# Early Effort and Schedule Models for Agile Projects in the US Department of Defense (DoD)

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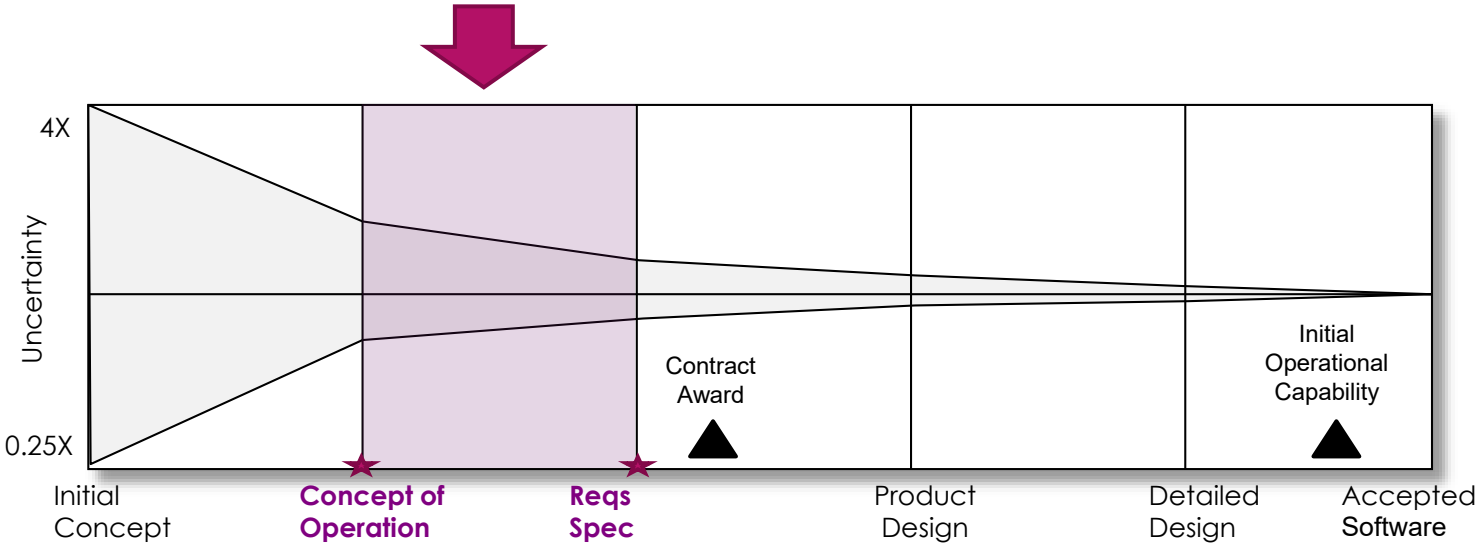
# What is the Problem?

- Cost estimates for agile software projects are very critical at early stages to evaluate contract proposals and to establish initial program budgets

- However, mainstream sizing measures are not practical for estimating agile projects at early life cycle as these are generated after contract award

# What is the Solution?

1. Choose an agile sizing measure available at early phase
2. Build practical estimation models for agile projects that can be used **early** in the project's lifecycle



# Outline

- Analytical Method
- Agile Project Dataset
- Agile vs Traditional Processes
- Effort Estimation Models
- Schedule Estimation Models
- Conclusion

# Analytical Method

*Six (6) easy steps to build Agile software cost and schedule models…*

# 1. DoD Data Collection Form:

## Software Resource Data Report (SRDR)

- A standardized mechanism to collect objective and measurable data on programs
- Required for software development contracts over $20M USD
- Includes fields for agile processes and metrics reporting

Submitted after contract start

SRDR Initial Developer Report

**Initial** Functional Requirements
**Initial** External Interfaces
**Initial** Peak Staff

Submitted after contract end

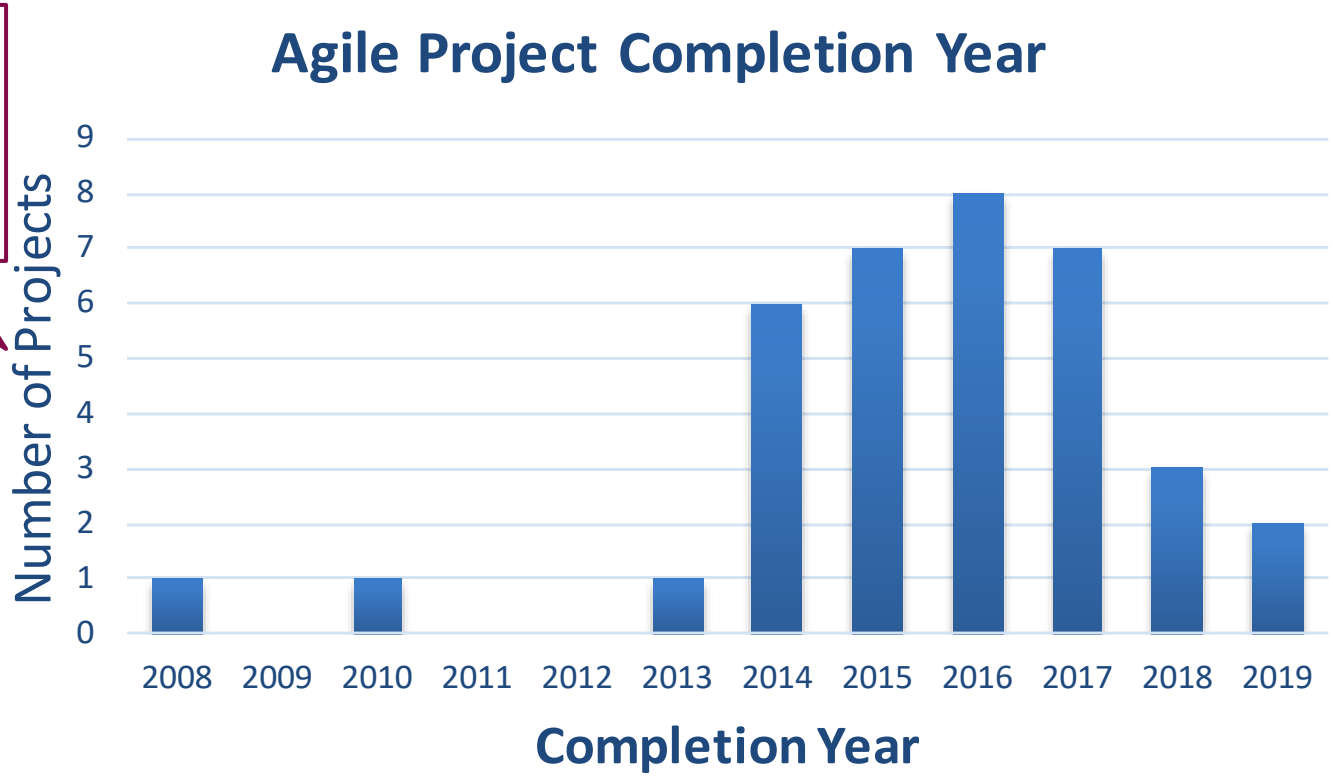
SRDR Final Developer Report

**Actual** Development Effort
**Actual** Development Schedule
**Actual** Development Process

Questionnaire: https://cade.osd.mil/Content/cade/files/csdr/guidance/DI-MGMT-82035A_SRDR%20Report.pdf
Form: https://cade.osd.mil/content/cade/files/csdr/dids/current/dd3026-1_2019.XLSX

# 2. Agile Project Dataset:

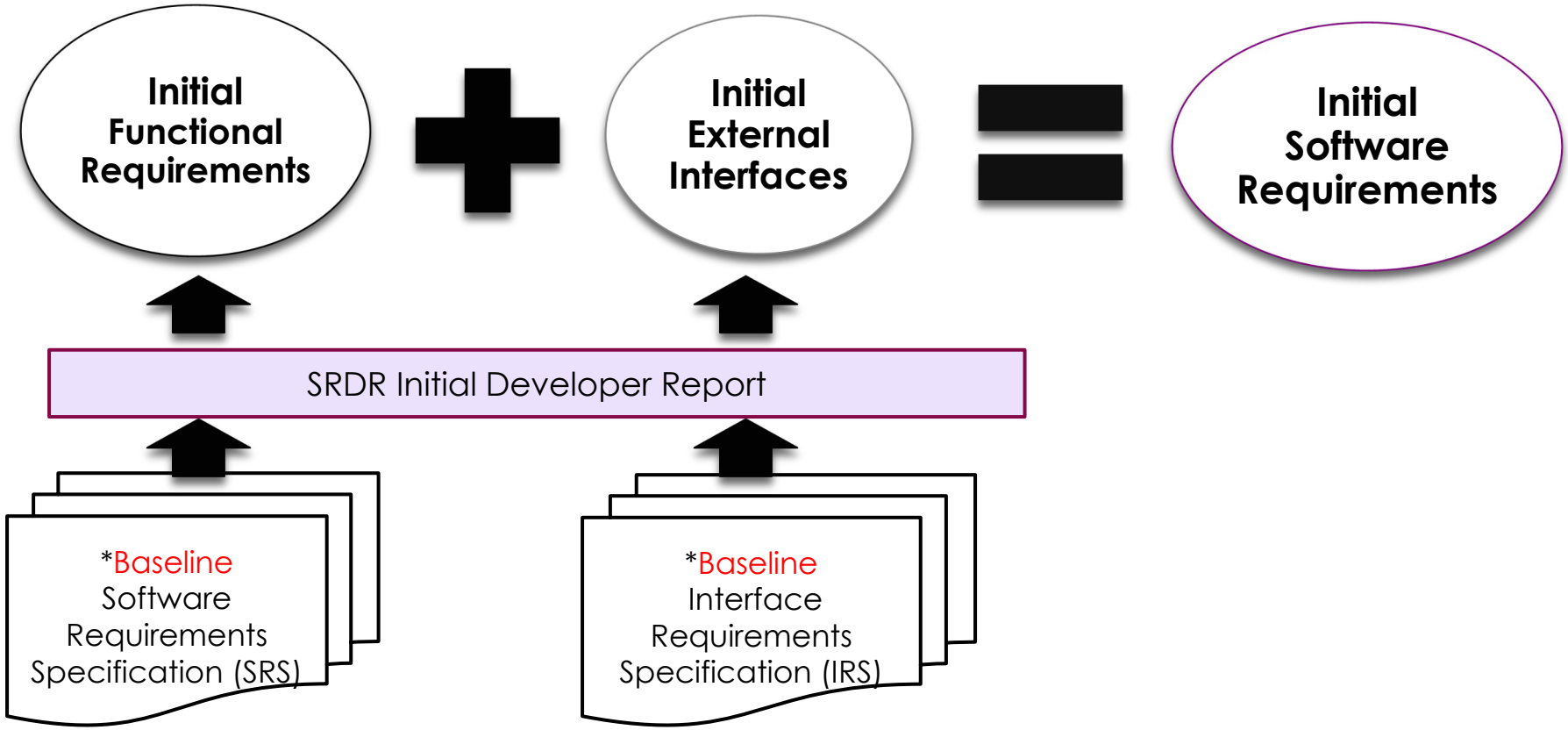
36 Agile Projects




Earlier projects (2008, 2010, 2013) used a tailored agile process by the developer

# 3. Agile Software Sizing Measure:

## Initial Software Requirements




*Baseline SRS and IRS are typically developed by the government before contract award
Developers will report the initial functional and external interface requirements in the SRDR Initial Developer Report

# 4. Group Dataset by Super Domain

- Dataset grouped into 4 complexity zones called **Super Domain**

| Super Domain | | Application Domain |
|---|---|---|
| Mission Support | SUPP | Software Tools |
| | | Training |
| Automated Information System | AIS | Enterprise Services |
| | | Custom AIS |
| | | Mission Planning |
| | | Enterprise Information System |
| Engineering | ENG | Scientific & Simulation |
| | | Test Measurement & Diagnostic Equipment |
| | | System Software |
| | | Process Control |
| Real Time Embedded | RTE | Command & Control, Communications |
| | | Real Time Embedded |
| | | Vehicle Control, Vehicle Payload |
| | | Signal Processing, Microcode & Firmware |

# 5. Variable Selection (Common Sense)

| Variable | ID | Type | Definition |
|---|---|---|---|
| Final Effort | E | Dependent | Actual development effort (in Hours) at contract end |
| Final Schedule | TDEV | Dependent | Actual development time (in Months) at contract end |
| Initial Software Requirements | REQ | Independent | Sum of Initial Functional Requirements and Initial External Interface Requirements reported at contract award. Counts "system shall" statements from baseline SRS and IRS. |
| Initial Peak Staff | Staff | Independent | Estimated peak staff (in full-time equivalent) at contract start |
| Super Domain | SD | Categorical (Dummy) | Treatment of the 4 (r) super domains required the addition of 3 (r-1) dummy variables denoted as:<br>D1 = 1 if AIS, 0 if SUPP or otherwise<br>D2 = 1 if ENG, 0 if otherwise<br>D3 = 1 if RTE, 0 if otherwise |

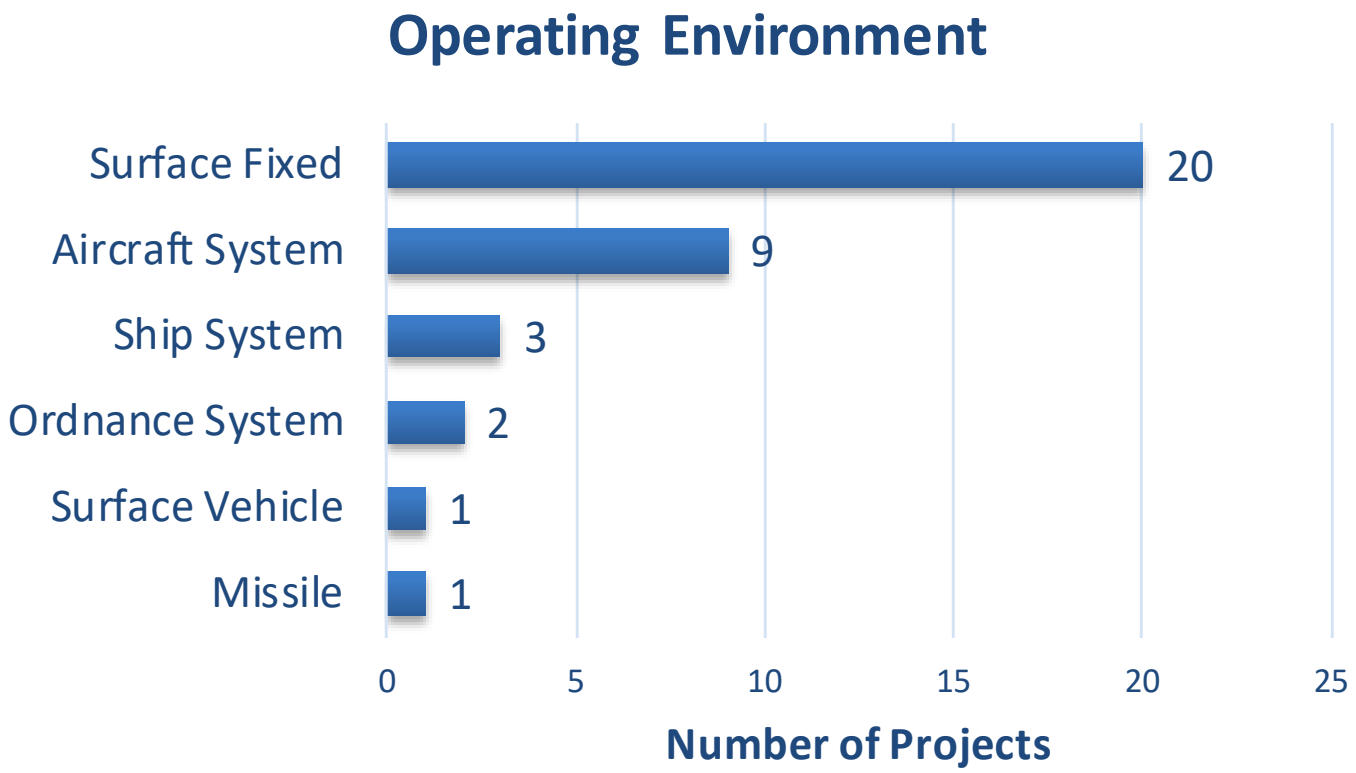
# 6. Model Selection Criteria

| Measure | ID | Description |
|---|---|---|
| Coefficient of Determination | $R^2$ | Coefficient of determination is the percentage of variation in the response explained by the model |
| Adjusted $R^2$ | $R^2$ (adj) | Percentage of the variation in the response explained by the model, adjusted for the # of predictors relative to the # of observations. |
| Predicted $R^2$ | $R^2$ (pred) | Involves removing each observation from the dataset, estimating the regression equation, determining how well the model predicts the removed observation, and repeats for all data points in the dataset. |
| Variance Inflation Factor | VIF | Indicates whether multi-collinearity (correlation among predictors) is present in a multi-regression analysis. |
| P-value | a | Statistical significance established through coefficient alpha (a = 0.05). |
| Mean Magnitude of Relative Error | MMRE | Mean Magnitude of Relative Error is an indicator of model's accuracy: Low MMRE= high accuracy |

# Agile Project Dataset

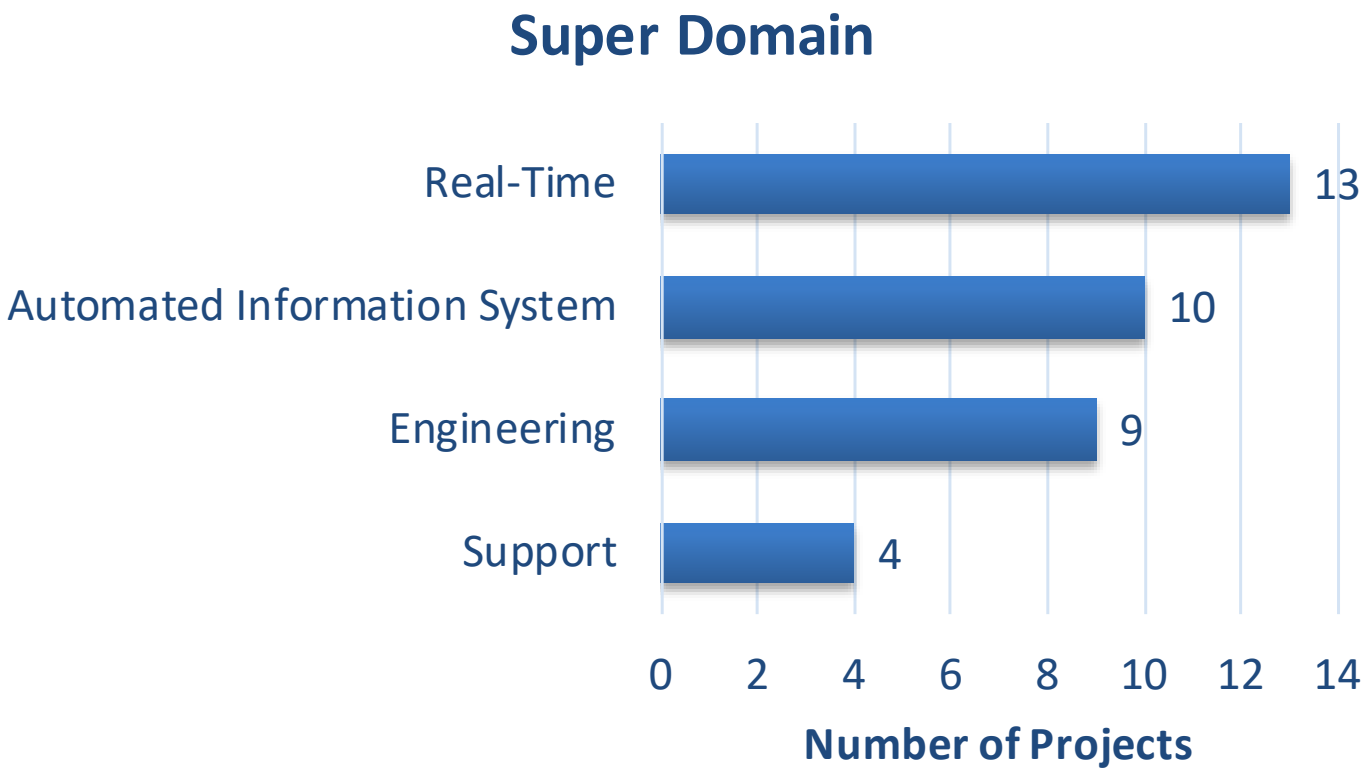
*Agile Project Characteristics and Descriptive Statistics*

# Dataset by Operating Environment

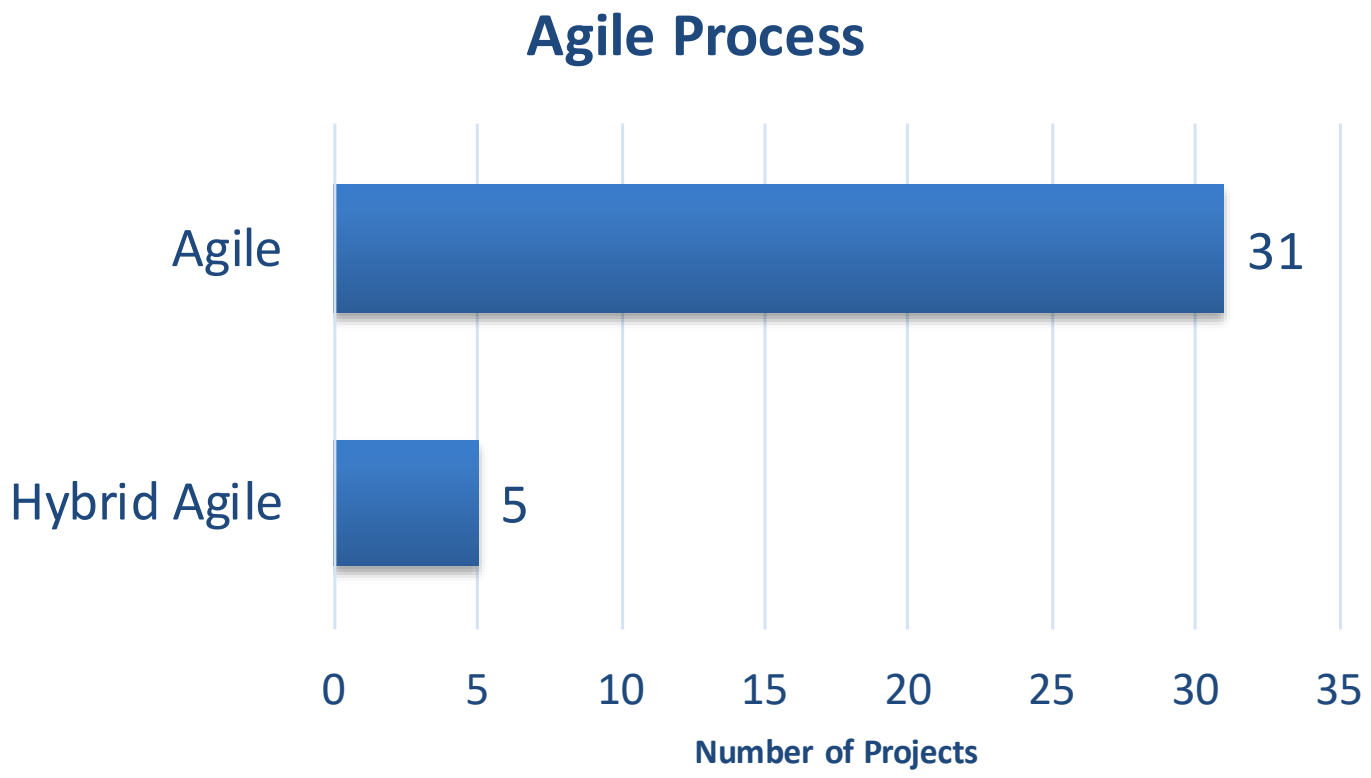



Most projects are hosted at a Surface Fixed or part of an Aircraft System

# Dataset by Super Domain

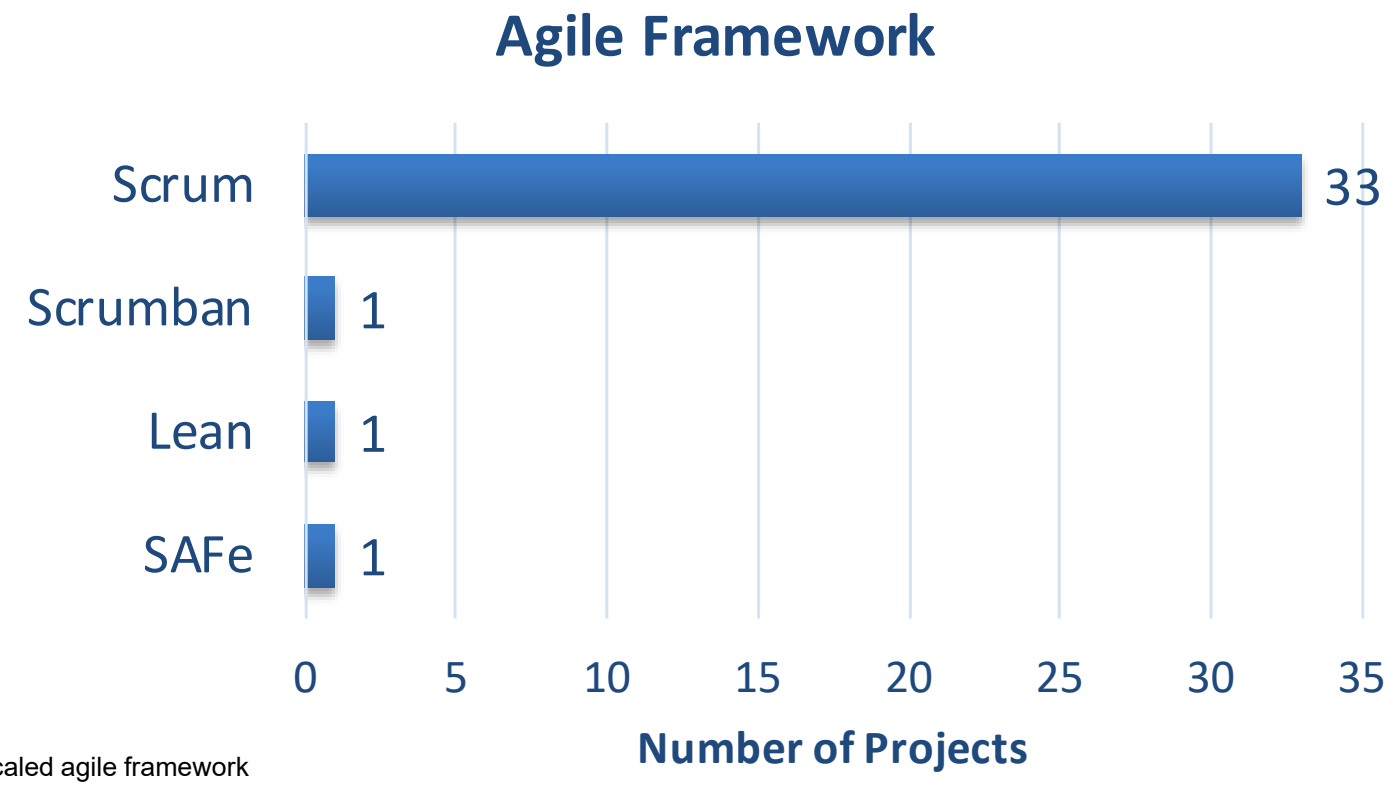


# Dataset by Agile Process




Hybrid Agile combines principles of Waterfall and Agile

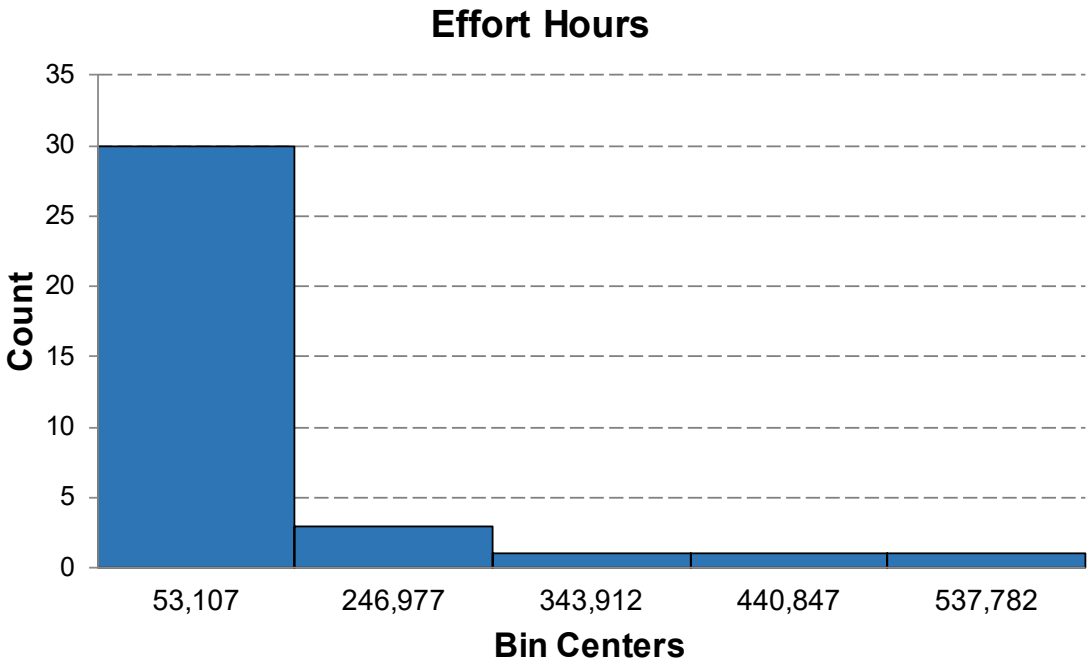
# Dataset by Agile Framework




SAFe = scaled agile framework

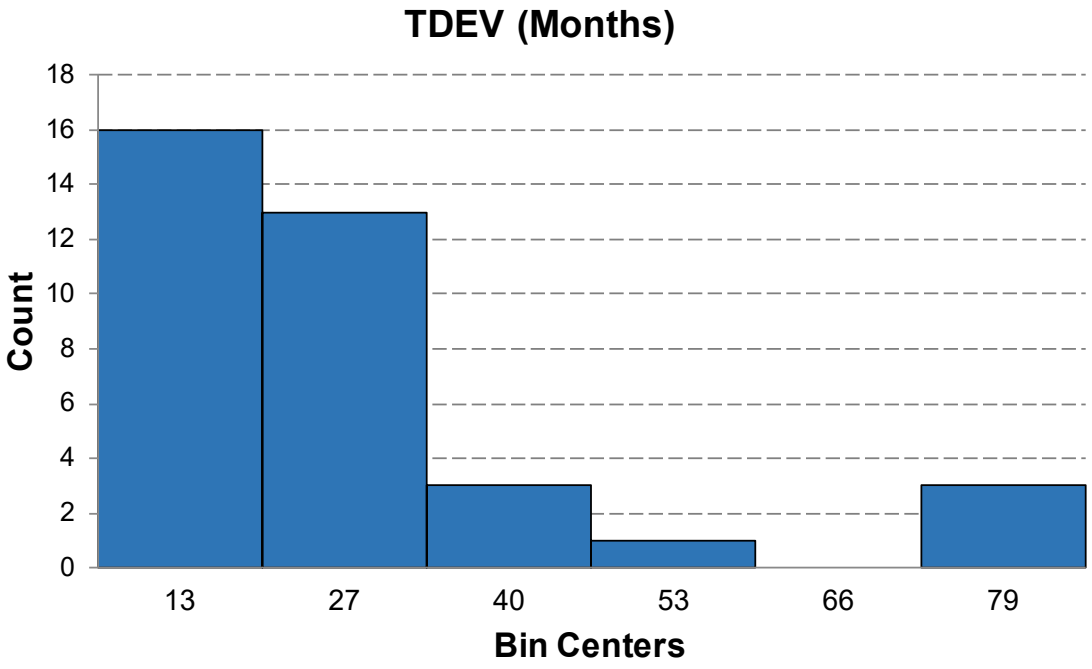
Scrum is the most common Agile framework in DoD

# Actual Effort Distribution



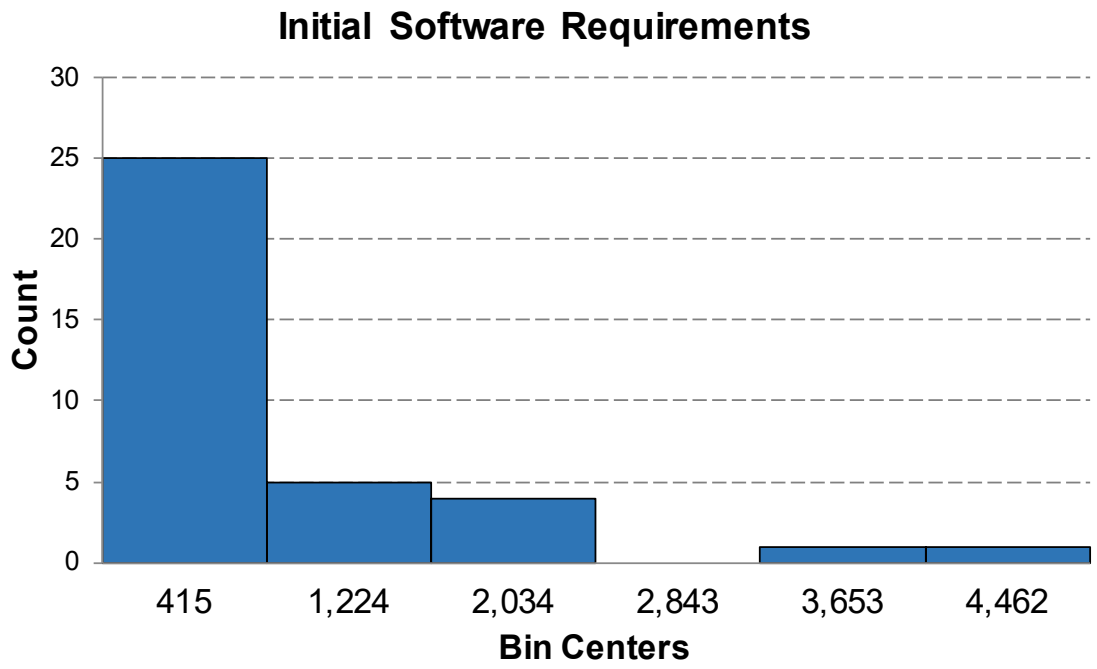

Average development effort for the agile project sample is 99,959 hours

# Actual Schedule Distribution



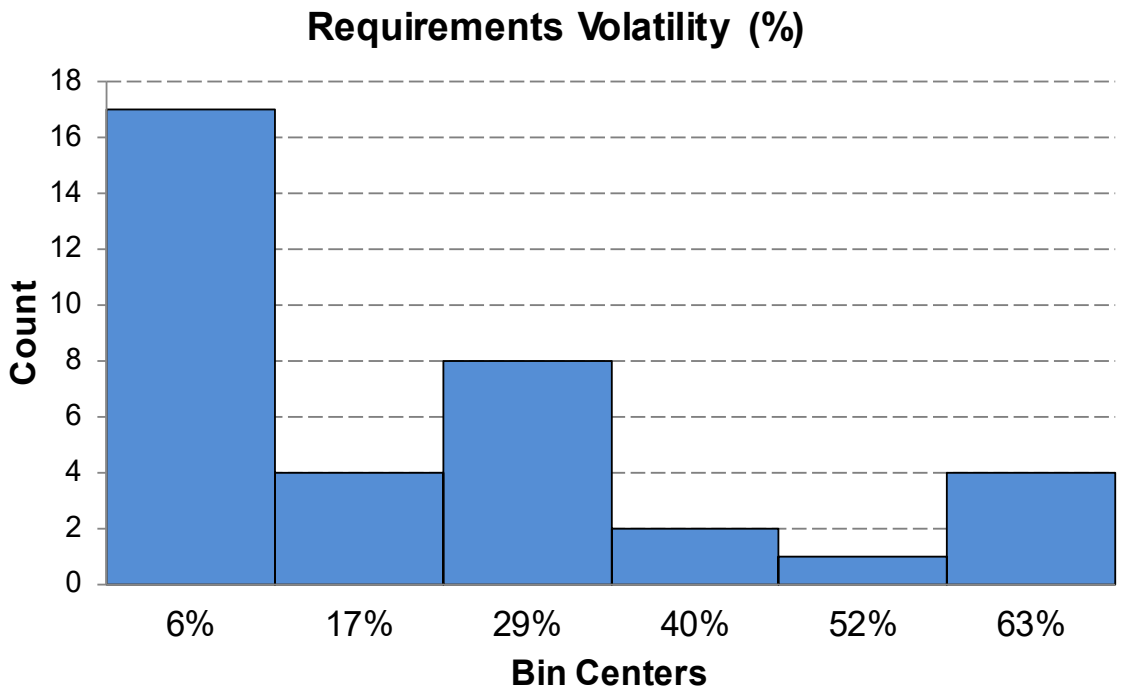

Average development time for the agile project sample is 26 months

# Initial Software Requirements




Average number of initial software requirements for the sample is 798

# Requirements Volatility (RVOL)




Average RVOL for the agile project sample is 19%

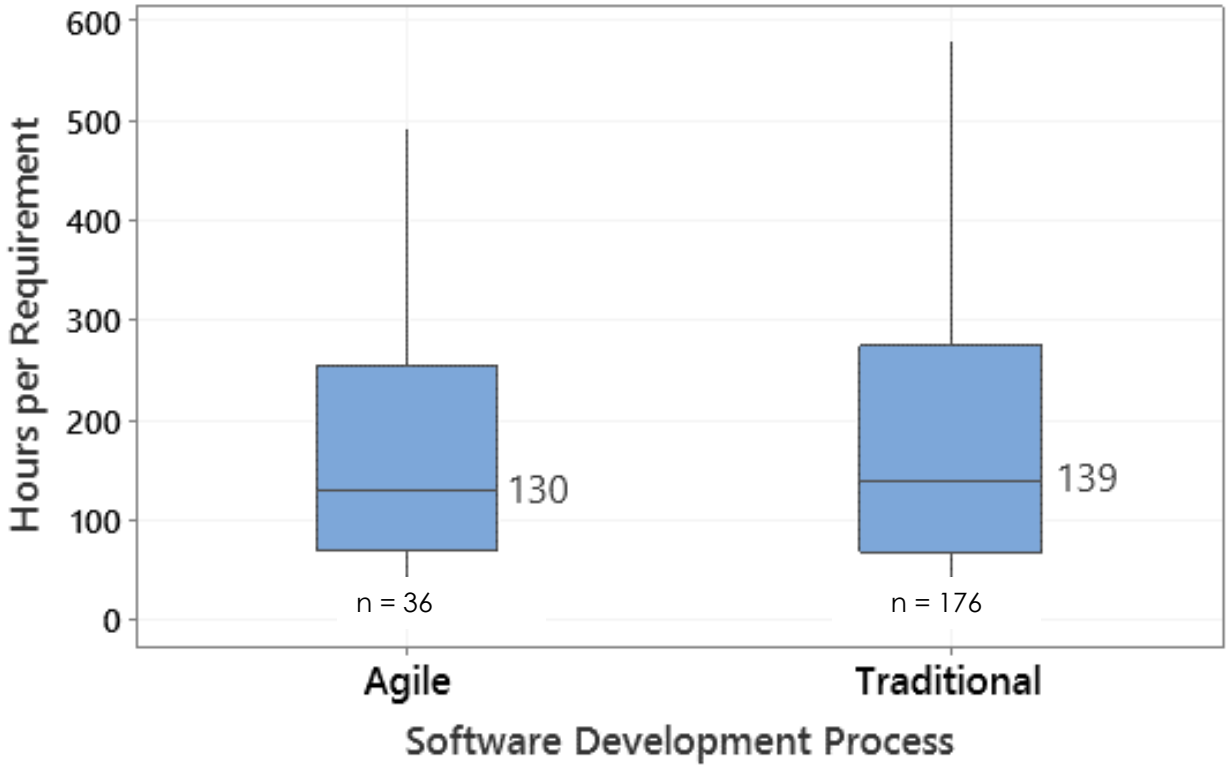
RVOL = requirements changes (added, modified, and deleted) divided by total initial software requirements

# Agile vs Traditional Process

How do Agile and traditional development processes compare for productivity, cost overruns, and team velocity in the US DoD?

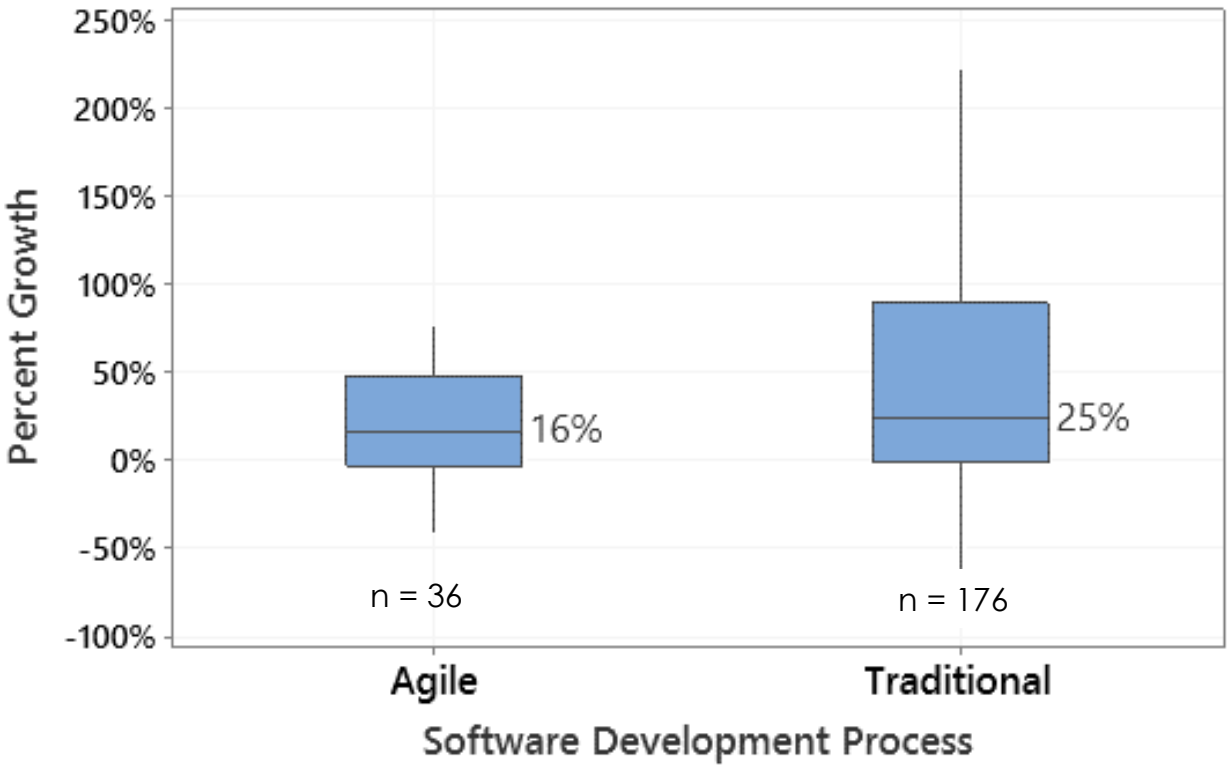
# DoD Software Productivity*

*Productivity = $\frac{Actual\ \ Development\ Hours}{Initial\ Software\ Requirements}$



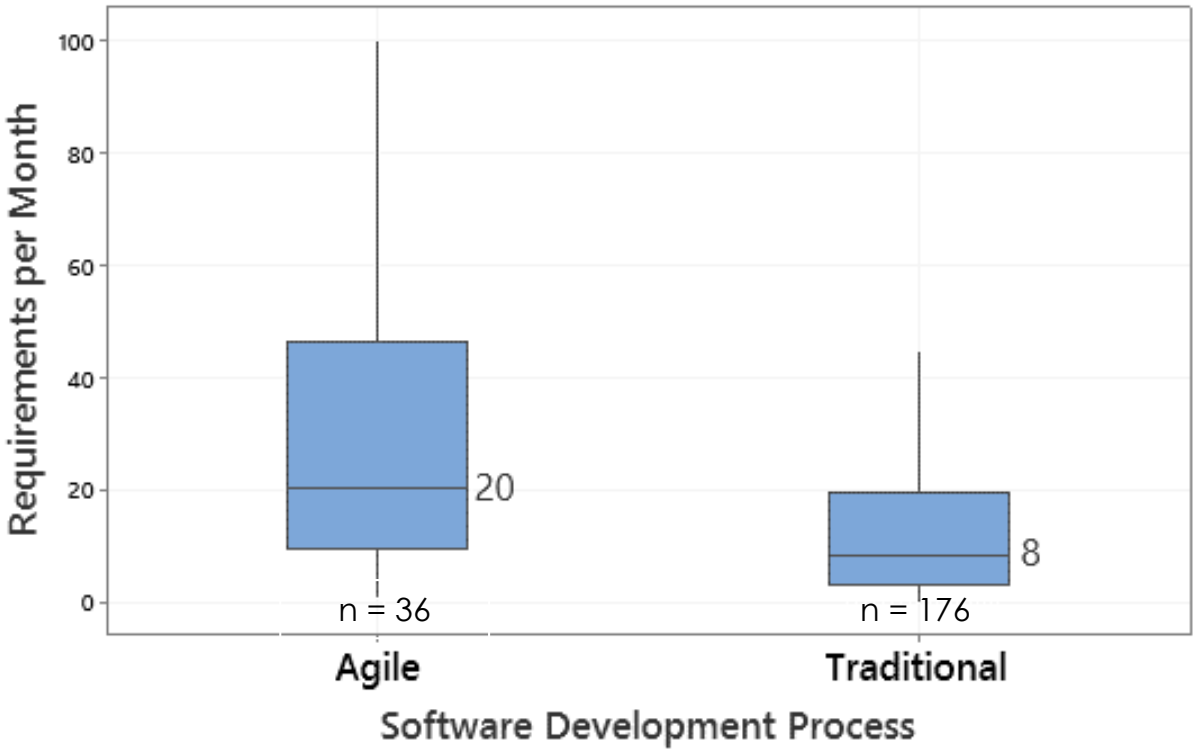
# DoD Software Development Overruns*

*Overrun = $\frac{Actual\ Hours}{Estimated\ Hours}$ - 1



# DoD Software Team's Velocity*

*Velocity = $\frac{Initial\ Software\ Requirements}{Actual\ Development\ Months}$



# Effort Estimation Models

*Simple effort estimation models (3) for Agile Projects!*

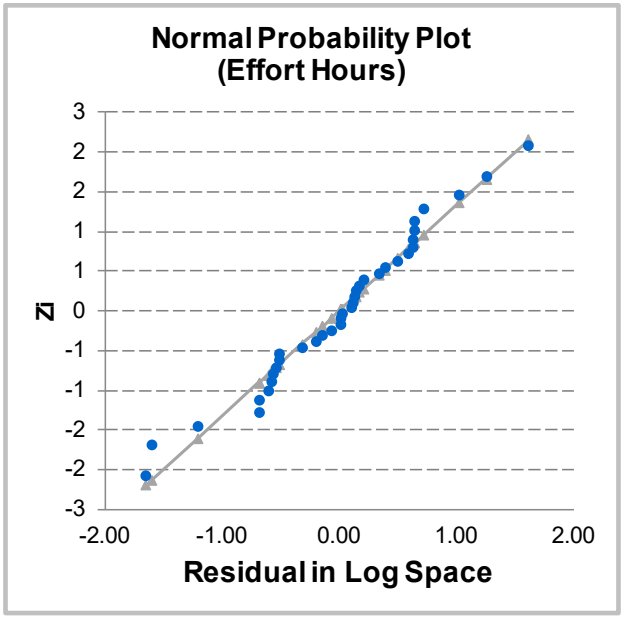
# Effort Model 1: One Variable

| Model | Equation Form | N | $R^2$ | $R^2$ (adj) | $R^2$ (pred) | MMRE |
|---|---|---|---|---|---|---|
| 1 | $E = 1006 \times REQ^{0.65}$ | 36 | 64% | 63% | 60% | 68% |

E = Final Effort (in Hours) at contract completion

REQ = Initial Functional Requirements + Initial External Interfaces

| Term | T-Statistic | P-value | VIF |
|---|---|---|---|
| Intercept | 13.7 | 0.0000 | *** |
| REQ | 7.8 | 0.0000 | *** |




- Useful for Rough Order of Magnitude or Business Case Analyses
- $R^2$ (adj) suggest adding variables to improve model reliability and accuracy

# Effort Model 2: Two Variable

| Model | Equation Form | N | $R^2$ | $R^2$ (adj) | $R^2$ (pred) | MMRE |
|---|---|---|---|---|---|---|
| 2 | $E = 200 \times REQ^{0.718} \times (3.0^{D1}) \times (3.6^{D2}) \times (5.1^{D3})$ | 36 | 80% | 77% | 73% | 47% |

E = Final Effort (in Hours) at contract completion

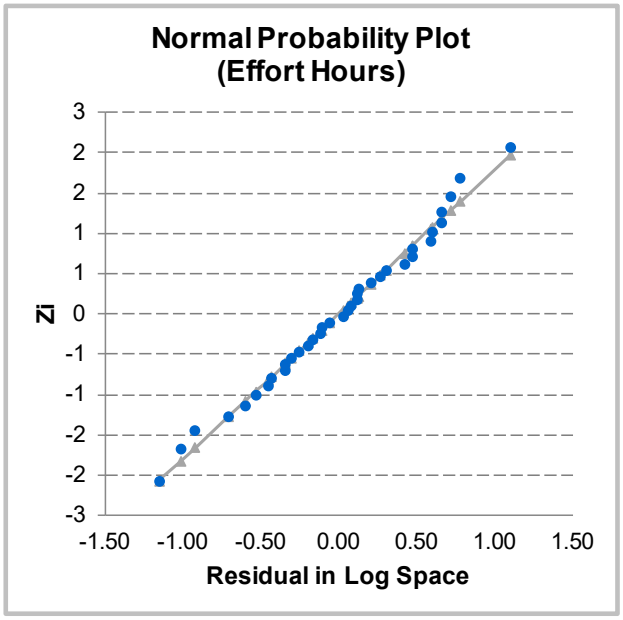
REQ = Initial Functional Requirements + Initial External Interfaces

**D1** = 1 if Automated Information System, 0 otherwise

**D2** = 1 if Engineering, 0 otherwise

**D3** = 1 if Real-Time Embedded, 0 otherwise

| Term | T-Statistic | P-value | VIF |
|---|---|---|---|
| Intercept | 9.7 | 0.0000 | |
| REQ | 10.2 | 0.0000 | 1.2 |
| **D1** | 3.2 | 0.0028 | 2.5 |
| **D2** | 3.5 | 0.0013 | 2.7 |
| **D3** | 4.9 | 0.0000 | 2.8 |




- Effort Model shows better fit and higher accuracy when super domain is added
- Useful for early estimates prior to the Request for Proposal

# Effort Model 3: Three Variable

| Model | Equation Form | N | $R^2$ | $R^2$ (adj) | $R^2$ (pred) | MMRE |
|---|---|---|---|---|---|---|
| 3 | $E = 173 \times REQ^{0.539} \times Staff^{0.463} (2.3^{D1}) \times (3.7^{D2}) \times (3.9^{D3})$ | 36 | 89% | 87% | 84% | 34% |

E = Final Effort (in Hours) at contract completion

REQ = Initial Functional Requirements + Initial External Interfaces

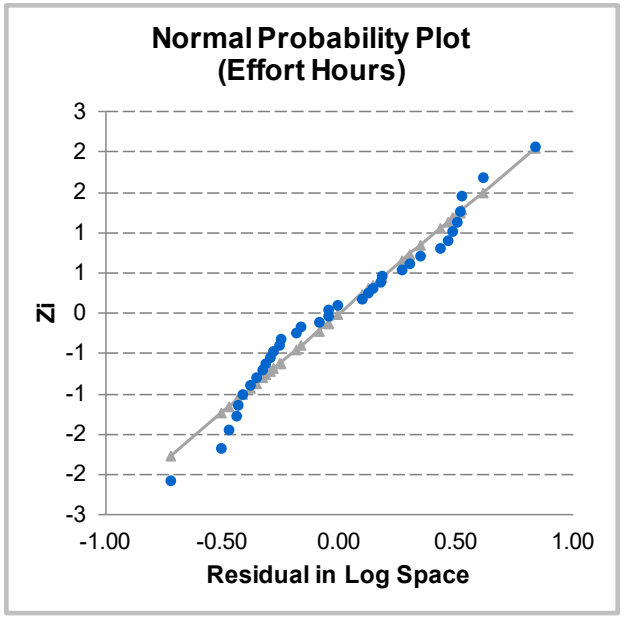
Staff = Initial Peak Staff at contract start

**D1** = 1 if Automated Information System, 0 otherwise

**D2** = 1 if Engineering, 0 otherwise

**D3** = 1 if Real-Time Embedded, 0 otherwise

| Term | T-Statistic | P-value | VIF |
|---|---|---|---|
| Intercept | 12.7 | 0.0000 | |
| REQ | 8.6 | 0.0000 | 1.7 |
| Staff | 5.2 | 0.0000 | 1.8 |
| **D1** | 3.3 | 0.0025 | 2.6 |
| **D2** | 4.9 | 0.0000 | 2.7 |
| **D3** | 5.5 | 0.0000 | 2.9 |




- Effort Model shows the best fit and highest accuracy when all three variables are added
- Useful for assessing contract cost proposals

# Schedule Estimation Models

*Simple schedule estimation models (2) for Agile Projects!*

# Schedule Model 1: Two Variable

| Model | Equation Form | N | $R^2$ | $R^2$ (adj) | $R^2$ (pred) | MMRE |
|---|---|---|---|---|---|---|
| 1 | $TDEV = 1.6 \times REQ^{0.272} \times (2.1^{D1}) \times (2.9^{D2}) \times (4.0^{D3})$ | 36 | 69 | 65 | 59 | 30 |

TDEV = Final Schedule (in Months) at contract completion

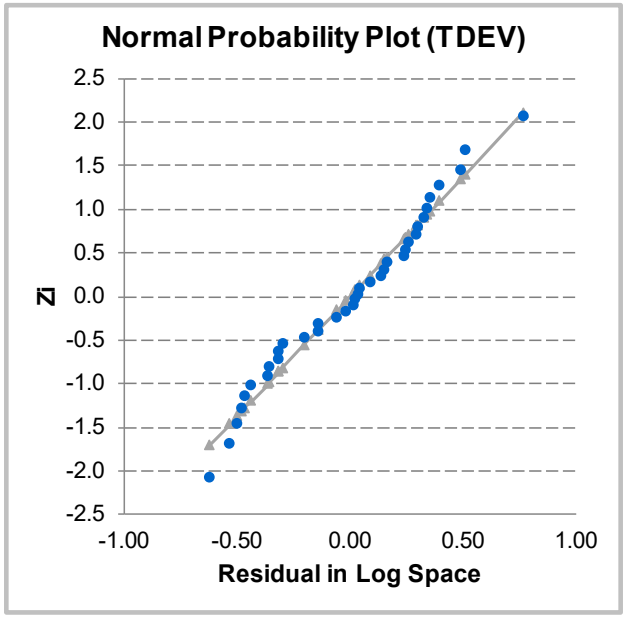
REQ = Initial Functional Requirements + Initial External Interfaces

**D1** = 1 if Automated Information System, 0 otherwise

**D2** = 1 if Engineering, 0 otherwise

**D3** = 1 if Real-Time Embedded, 0 otherwise

| Term | T-Statistic | P-value | VIF |
|---|---|---|---|
| Intercept | 1.40 | 0.1724 | |
| REQ | 5.97 | 0.0000 | 1.2 |
| **D1** | 3.49 | 0.0015 | 2.5 |
| **D2** | 4.69 | 0.0001 | 2.7 |
| **D3** | 6.56 | 0.0000 | 2.8 |




- Schedule Model shows good fit and high accuracy
- Useful for early schedule estimates or assessments

# Schedule Model 2: Three Variable

| Model | Equation Form | N | $R^2$ | $R^2$ (adj) | $R^2$ (pred) | MMRE |
|---|---|---|---|---|---|---|
| 2 | $TDEV = 1.7 \times REQ^{0.34} \times Staff^{-0.19} (2.3^{D1}) \times (3.0^{D2}) \times (4.5^{D3})$ | 36 | 75% | 70% | 63% | 27% |

TDEV = Final Schedule (in Months) at contract completion

REQ = Initial Functional Requirements + Initial External Interfaces

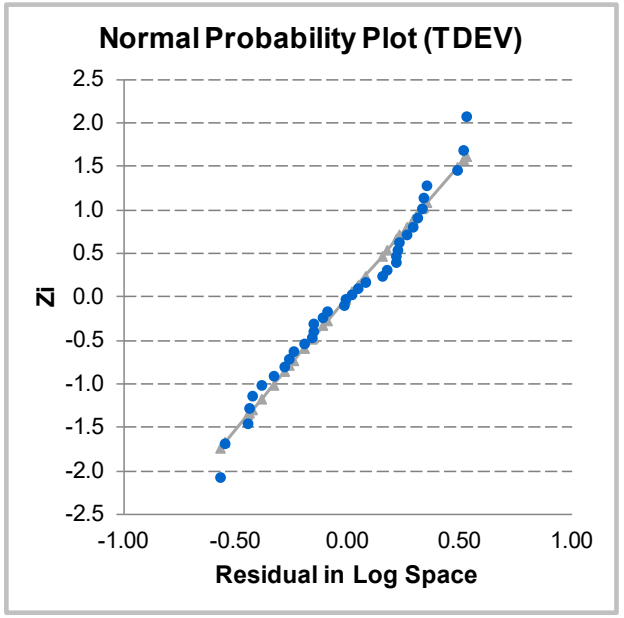
Staff = Initial Peak Staff at contract start

**D1** = 1 if Automated Information System, 0 otherwise

**D2** = 1 if Engineering, 0 otherwise

**D3** = 1 if Real-Time Embedded, 0 otherwise

| Term | T-Statistic | P-value | VIF |
|---|---|---|---|
| Intercept | 1.7 | 0.0986 | |
| REQ | 6.9 | 0.0000 | 1.7 |
| Staff | -2.6 | 0.0135 | 1.8 |
| **D1** | 4.2 | 0.0002 | 2.6 |
| **D2** | 5.1 | 0.0000 | 2.7 |
| **D3** | 7.5 | 0.0000 | 2.9 |




- Schedule Model shows better fit and higher accuracy when all three variables are added
- Useful for assessing realism of cost proposals

# Conclusion

# Main Takeaway

Results confirmed that Initial, as opposed to final, software requirements, along with super domain and peak staff, proved to be effective in estimating effort and schedule for agile projects at early lifecycle in DoD

“Agile estimation is not rocket science
but it takes Perseverance to build a useful cost model”

- Dr. Wilson Rosa -